NONINVASIVE SENSOR FOR MEASURING MUSCLE METABOLISM DURING EXERCISE

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INTRODUCTION

The measurement of oxygen uptake (VO_2) and lactate threshold (LT) are utilized to assess changes in aerobic capacity and the efficacy of exercise countermeasures in astronauts. During extravehicular activity (EVA), real-time knowledge of VO_2 and relative work intensity can be used to monitor crew activity levels and organize tasks to reduce the cumulative effects of fatigue. Currently VO_2 and LT are determined with complicated measurement techniques that require sampling of expired ventilatory gases, which may not be accurate in enclosed, oxygen-rich environments such as the EVA suit.

The UMMS team has developed a novel near infrared spectroscopic (NIRS) system which noninvasively, simultaneously and continuously measures muscle oxygen tension, oxygen saturation [1], pH (pHm) [2,3], and hematocrit from a small sensor placed on the leg. This system is unique in that it allows accurate, absolute measurement of these parameters in the thigh muscle by correcting spectra for the interference from skin pigment and fat [4]. These parameters can be used to estimate VO_2 and LT. A preliminary evaluation of the system's capabilities was performed in the NASA JSC Exercise Physiology Lab.

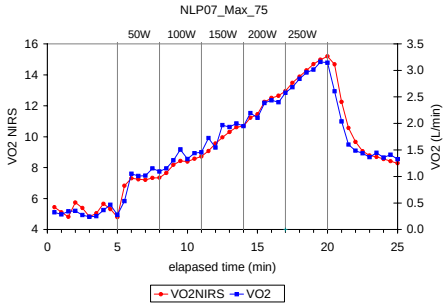
METHODS

Ten subjects (5M/5F) performed a maximal cycle ergometry protocol (50W increments every 3rd min) to exhaustion. Near infrared spectra were collected by the UMMS NIRS system every few seconds with a sensor placed on the vastus lateralis. VO_2 and carbon dioxide production were measured using a metabolic cart (True One 2400, Parvo Medics, Salt Lake City, UT). In the last 30 sec of each stage, a small blood sample was obtained from the finger tip for the measurement of blood lactate (YSI 1500 SPORT, YSI Life Sciences, Yellow Springs, OH).

VO_2 was estimated solely from NIRS-derived parameters and was compared to VO_2 measured by the metabolic cart using a biavariate correlation. The hydrogen ion concentration [H^+] was calculated from the NIRS pH determination. Lactate measurements were interpolated to 30 sec values from the measurements at each stage. LT was determined as a function of VO_2 from both the interpolated lactate and [H^+] measurements using a non-linear regression and defined as the VO_2 at which point the slope in lactate and [H^+] production increased with incrementally greater work.

RESULTS

NIRS-derived VO_2 and measured VO_2 were highly correlated within individual subjects (avg R^2=0.96). One subject is shown as an example in the Figure. Also, VO_2 at LT determined from lactate and [H^+] were highly correlated (R^2 = 0.90) across all subjects.



DISCUSSION AND CONCLUSIONS

The UMMS NIRS system shows potential for providing real-time assessment of VO_2 and LT with a small, body-worn sensor during fitness assessments and EVA. The miniaturization of this device for on-orbit use, particularly in the EVA suit, and the extension of this work to calculate absolute values for VO_2 are planned.

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